Current Practices for Radiant System Design

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Taylor Engineering

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TRC Energy Services
Overview: EPIC* radiant systems project

**Project Title**
- Optimizing radiant systems for energy efficiency and comfort

**Project Overview**
- Start date: September 2015; 4-year project
- Budget: $3.2M
  - $2.9M – California’s EPIC Grant Program
  - $300K – 10% match funding (CBE: $240K; Price Industries: $60K)
- Research team: CBE, Taylor Engineering, TRC Energy Services, New Buildings Institute, Price Industries

[http://www.cbe.berkeley.edu/research/optimizing-radiant-systems.htm](http://www.cbe.berkeley.edu/research/optimizing-radiant-systems.htm)

*Electric Program Investment Charge (EPIC)*
1. **Current Practices for Radiant System Design**
   Results of interviews with expert radiant system designers
   *Gwelen Paliaga, TRC*

2. **Comparison of Cooling Rates for Radiant and All-Air Systems**
   Full-scale FLEXLAB experiments
   *Jonathan Woolley, CBE*

3. **ARTIC Radiant Case Study**
   Field study results from a high-performing radiant floor transit center
   *Jovan Pantelic, CBE*
Current practices for radiant system design

Objective

- Document design and control approaches used for radiant cooling

Approach

- 11 prominent professionals who have designed ~ 330 radiant cooling projects
- Interview & review control sequences
- Focus areas
  - Controls sequences of operation (SOO)
  - High mass radiant cooling (TABS & ESS)

Team

- TRC Energy Services - Gwelen Paliaga, Farhad Farahmand
- CBE - Jonathan Woolley, Paul Raftery
Study approach: Structured interview process

- Identify Experts
- Structured Interview Guide
- Recorded Phone Interview
- Categorize & Count Responses

### Interview Topics
- Interviewee background
- System configuration
  - Slab configuration
  - Supplemental cooling systems
  - Ventilation systems
  - Zoning
- Controls and sequence of operation
  - Slab temperature control
  - Zone air temperature control
  - Interaction between radiant cooling and supplemental cooling
  - Condensation control
  - Ventilation systems control
- System commissioning

70 Page Report with Detailed Analysis of Each Topic
- Narrative
- Tables
- Quotes
- Examples SOOs
Three key perspectives on high mass radiant cooling

- **Limited Cooling Capacity**
  - Lower than conventional systems (except in direct sun)

- **High Thermal Inertia**
  - Slab temperature changes slowly

- **Self-regulation**
  - Heat transfer to the cooled slab surface naturally and instantaneously responds to changes in air temperature
Common practices

High Thermal Inertia & Limited Cooling Capacity

- Critical to reduce envelope and internal load (use “integrated design”)
- Radiant performs best with low load variability
  - Except when direct solar strikes floor
- Large zones with relatively constant slab temperature
- Supplemental cooling often used

Dedicated Outdoor Air System (DOAS) & Supplemental Cooling

- All use DOAS for ventilation
- Most up-size DOAS for supplemental cooling to:
  - Cool when peak loads are higher than radiant capacity
  - Respond quickly to zones with variable load (e.g. conference room)

“Buildings with bad envelopes need supplemental cooling. In conference rooms the air provides supplemental cooling. There’s always a couple spots you need more air, but mostly the radiant can meet the load in well-designed buildings with good solar control.”
Common practices

Self-Regulation
- Key explanation for comfort performance allowing:
  - Large radiant zones with nearly constant slab temperature setpoint
  - Simplified supplemental cooling system (avoid fully VAV DOAS system)

Slab Design & Temperature Control
- Activate as much mass as possible
- Use for both radiant cooling and heating
- Maintain relatively constant temperature
  - With seasonal or weather based resets
  - Slab active 24/7 without setback
  - Rarely pre-cool slab

“[Slab temp] set point is pretty much a steady state, trying to keep things simplified. The ventilation air is what tweaks the space temperature.”
Common practices

Post Occupancy Commissioning

“With heavy mass systems, to do it properly requires close monitoring for at least a full year of performance.”

“In some cases, maybe a few zones, we actually throttle down the flow to the loop serving that area.”

“We provide direct support to the operator for maybe a year or nine months.”
Summary of differences in common practice

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating/Cooling Mode Changeover</td>
<td>• Wide variety of approaches</td>
</tr>
<tr>
<td>Supplemental Cooling</td>
<td>• Wide variety of designs</td>
</tr>
<tr>
<td></td>
<td>• Wide variety of control SOO</td>
</tr>
<tr>
<td>High Mass Radiant Cooling Applicability</td>
<td>• Most space types</td>
</tr>
<tr>
<td></td>
<td>• Only specific space types</td>
</tr>
<tr>
<td>Zone Control Device</td>
<td>• Valves</td>
</tr>
<tr>
<td></td>
<td>• Pumps</td>
</tr>
<tr>
<td>Radiant Control Valves</td>
<td>• 2-position</td>
</tr>
<tr>
<td></td>
<td>• Modulating</td>
</tr>
<tr>
<td>Active Condensation Control</td>
<td>• Yes</td>
</tr>
<tr>
<td></td>
<td>• No</td>
</tr>
<tr>
<td>Temp Offset to Prevent Condensation</td>
<td>• Chilled water above dewpoint</td>
</tr>
<tr>
<td></td>
<td>• Slab surface above dewpoint</td>
</tr>
<tr>
<td>Chilled Water Plant Sizing</td>
<td>• Same as conventional VAV</td>
</tr>
<tr>
<td></td>
<td>• Smaller size accounting for thermal storage</td>
</tr>
<tr>
<td>Slab Temperature Sensor Location</td>
<td>• Near surface</td>
</tr>
<tr>
<td></td>
<td>• At Tubing depth</td>
</tr>
<tr>
<td>Chilled Water Plant Temperature</td>
<td>• Low Temperature</td>
</tr>
<tr>
<td></td>
<td>• High Temperature</td>
</tr>
</tbody>
</table>
**Difference in common practices (example)**

**Radiant Zone Control Device**

<table>
<thead>
<tr>
<th>How do you control radiant zones?</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two position zone valves</td>
<td>6</td>
</tr>
<tr>
<td>Modulating zone valves</td>
<td>4</td>
</tr>
<tr>
<td>Pumps with 3-way control valves at the zone</td>
<td>3</td>
</tr>
<tr>
<td>Constant speed pump</td>
<td>1</td>
</tr>
<tr>
<td>Variable speed pump</td>
<td>1</td>
</tr>
</tbody>
</table>

“The slab temperature reacts so slowly that modulating valves effectively operate in 2-position”
## Difference in common practices (example)

### Slab Heating/Cooling Changeover

<table>
<thead>
<tr>
<th>How is the changeover from heating to cooling controlled?</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Force radiant slab to turn off</td>
<td>8</td>
</tr>
<tr>
<td>Time delay between heating and cooling</td>
<td>2</td>
</tr>
<tr>
<td>Dead band or lockout between heating and cooling</td>
<td>5</td>
</tr>
<tr>
<td>Limit the rate of change &amp; reset to neutral before changing modes</td>
<td>4</td>
</tr>
<tr>
<td>Seasonal slowly changing: on the scale of days to weeks</td>
<td>3</td>
</tr>
</tbody>
</table>

“Changeover is based on space air temperature. We put in a two hour lockout for the slab during changeover. There is a low delta temperature between the slab and air anyway...”
Difference in common practices (example)

Chilled Water Plant Supply Temperature

<table>
<thead>
<tr>
<th>Do you supply chilled water (CHW) at a higher temperature than a typical HVAC system?</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional chilled water plant</td>
<td>18</td>
</tr>
<tr>
<td>Plant produces CHW in mid 40s (°F) – blend with return water for radiant cooling</td>
<td>8</td>
</tr>
<tr>
<td>Two CHW plants: high temp for radiant – low temp for dehumidification, AHUs, fan coils</td>
<td>7</td>
</tr>
<tr>
<td>High temp CHW for radiant – alternative dehumidification (passive, none)</td>
<td>3</td>
</tr>
<tr>
<td>Compressorless chilled water plant</td>
<td>4</td>
</tr>
</tbody>
</table>

“Some buildings have been whole building at 58F (high temperature) just above dew point, with large cooling coils in air systems. In other systems we blend down for radiant systems in order to allow lower chilled water for others systems, especially process loads and dehumidification.”
Summary and next steps

Summary

- Wide diversity of design and control solutions
  - Some differences depend on specific projects
  - Many differences reveal opportunities for improvement and standardization
- Much more information in 70 page report
  - Including example control sequences
  - Potential for improvement
  - Future research topics

Next Steps

- Finalize report (very soon)
- Develop new control sequences & field test (CBE)
  - Simulation study accepted for publication in August
- Seek funding to create a best practice guide
Please take a moment to fill out the feedback form.